Testing & Development of W Rod Tiles for C-MOD

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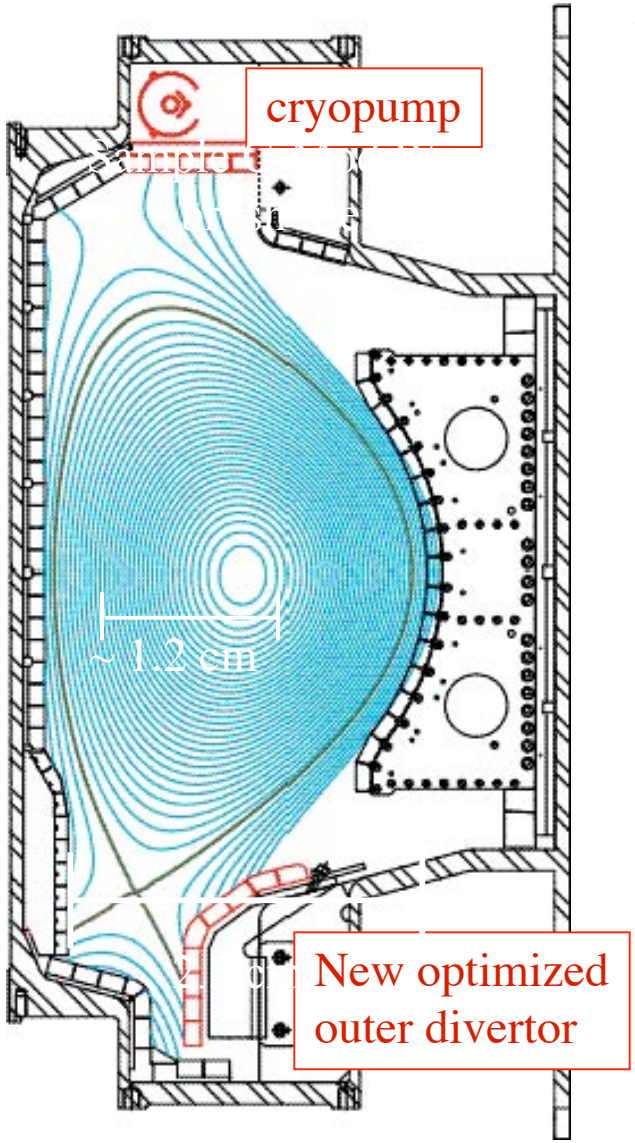
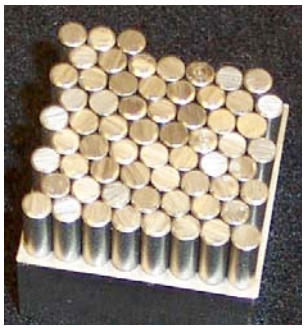
Dennis Youchison	Sandia, testing
Tom Lutz	Sandia, testing
Ken Troncosa	Sandia, testing
Fred Bauer	Sandia, testing
Chuck Walker	Sandia braze
Carter Hodges	Sandia braze
C-MOD Team	MIT, tile design/fab

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

Excerpts from MIT presentation on Alcator C-Mod to C-Mod PAC Feb 2004



- .. divertor target materials (high Z)
  - Prototype tungsten brush modules (near term)
- Tungsten brush tiles .. proposed for BPXs
  - .. handle up to 20 MW/m^2 steady state
  - resists melt layer formation
  - no tokamak experience



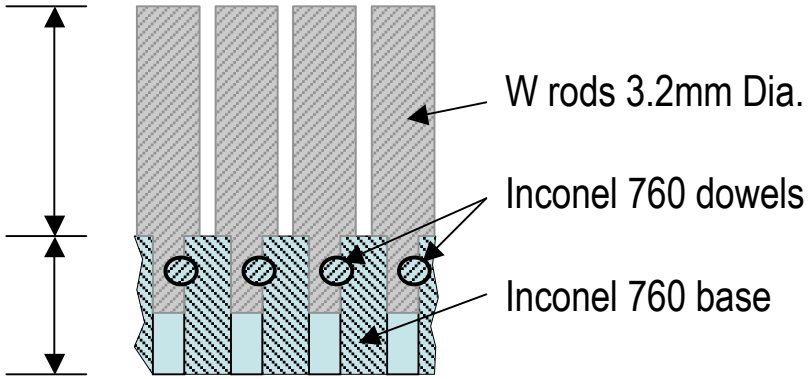
- C-Mod is working towards W-brush tile installation & testing
  - based on original Sandia design
  - collaboration with Sandia
- C-Mod design aimed at
  - simplified construction and manufacture
  - maximization of W/support interface
- Plans
  - 2 different tile designs being manufactured & tested
  - plan for installation of ~ 5-10 tiles next vacuum break

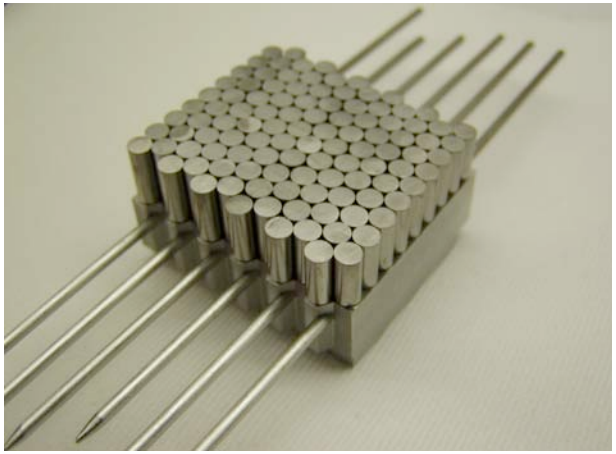
Design of C-MOD W-rod tiles

Sandia had initially suggested to MIT a tile design based on W rod armor originally developed by the US Team for ITER in the late 1990's.

The cost, for a small lot of tiles embedded in a plasma-sprayed base, and lack of a positive lock of the rods into the base, if the joint loosened, were noted as potential issues for this design.

MIT developed a scheme with W rods tethered to an Inconel 760 base.





C-MOD W-rod tiles – MIT/Sandia Collaboration

- MIT and Sandia collaborated on designs for W rod tiles for C-MOD.
- Sandia tested the first mockups (mechanically attached rods).
- In tests in EBTS, a plasma formed at the surface of the rods due (we presume) to charging of the rods and ionization of residual gas.
- Sandia then suggested brazing the W rods into the base.
- No plasma formed in the tests of brazed tiles.
- Brief thermal performance tests on a brazed tile and calorimetry on an isolated W rod provide some data on $T_{surface}$ versus $q''_{absorbed}$.

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- Brief thermal performance tests on a brazed tile and calorimetry on an isolated W rod provide some data on $T_{surface}$ versus $q''_{absorbed}$.
- With an optimized procedure, Sandia brazed sets tiles for destined for C-MOD.

Bruce, [Lipschultz]

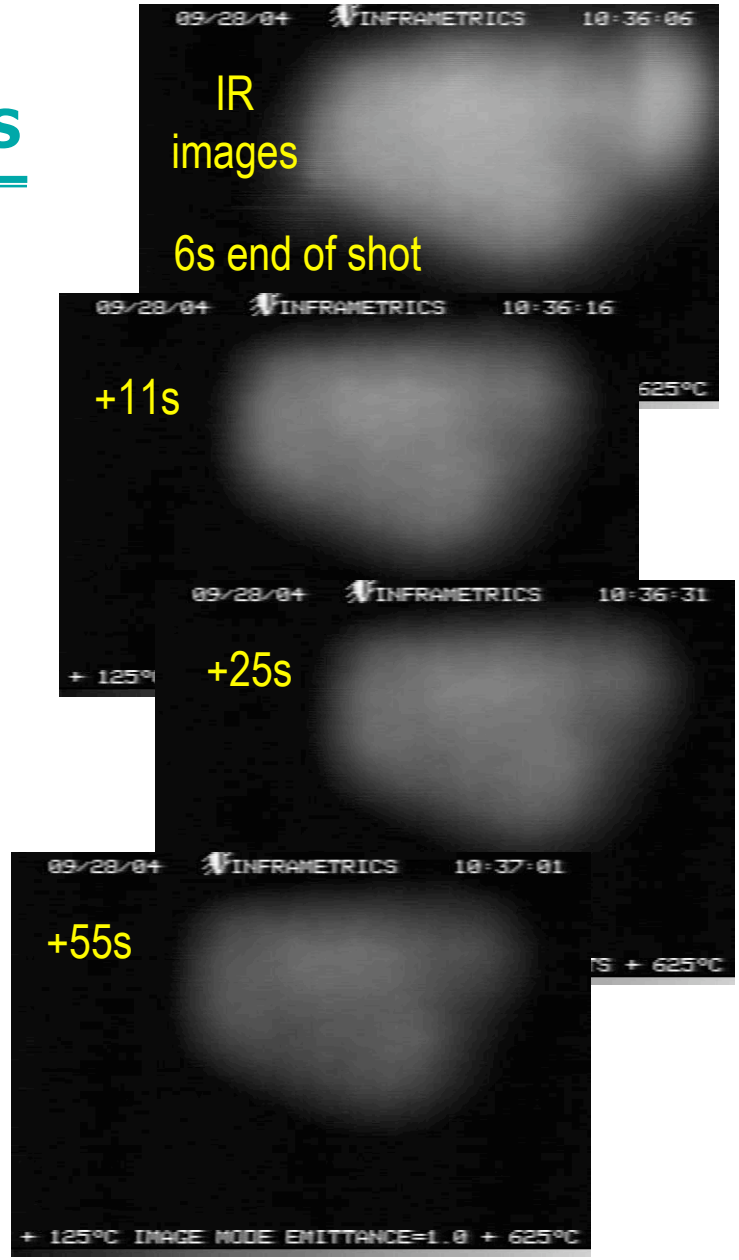
Not sure if Sam told you, but the brazed tiles are back from Sandia. They look beautiful. I've looked down every hole with the microscope in two of the tiles so far, and the braze flowed well w/o any excess...

Thank you Sandia....
Jim [Irby]

C-MOD tile – 1st test series in EBTS

- Heat loads of ~??MW/m^2
- Fuzzy glow appeared at tile surface.
- Glow persisted after shot.
- Conclusion: plasma formed at the tile surface and sustained itself.
- Measuring the temperature of the W rods with IR was not possible due to plasma.
- Formation of a plasma suggests that the mechanically tethered rods were not adequately grounded.

****** important result for C-MOD ******



C-MOD tile – 1st test series in EBTS

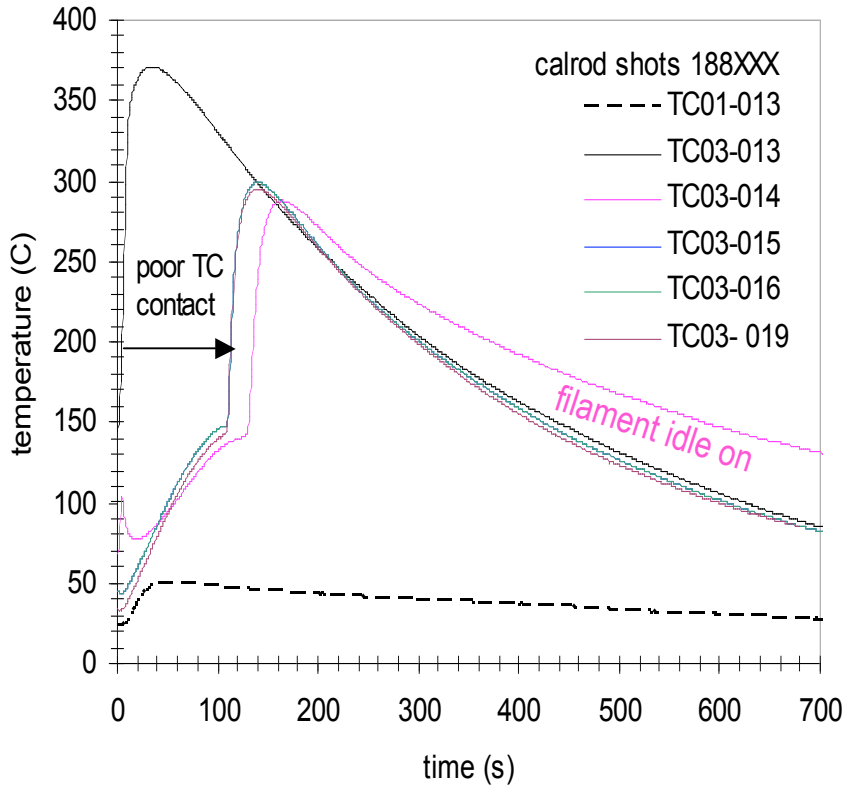
What are the temperature and heat flux?

Challenges:

- W reflects ~70% of beam
- Pyrometer spots > rod dia.
- No welded/brazed thermocouples (TCs)

What is the absorbed power fraction?

$f_{abs} = q''_{abs}/q''_{beam}$



CalRod cooling curves

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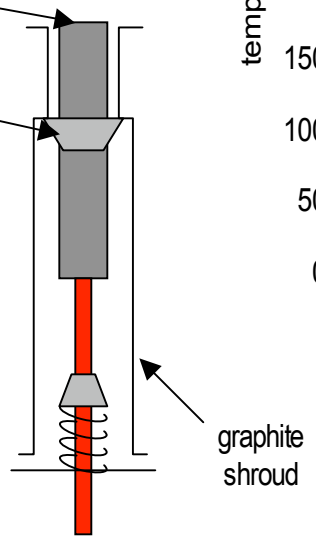
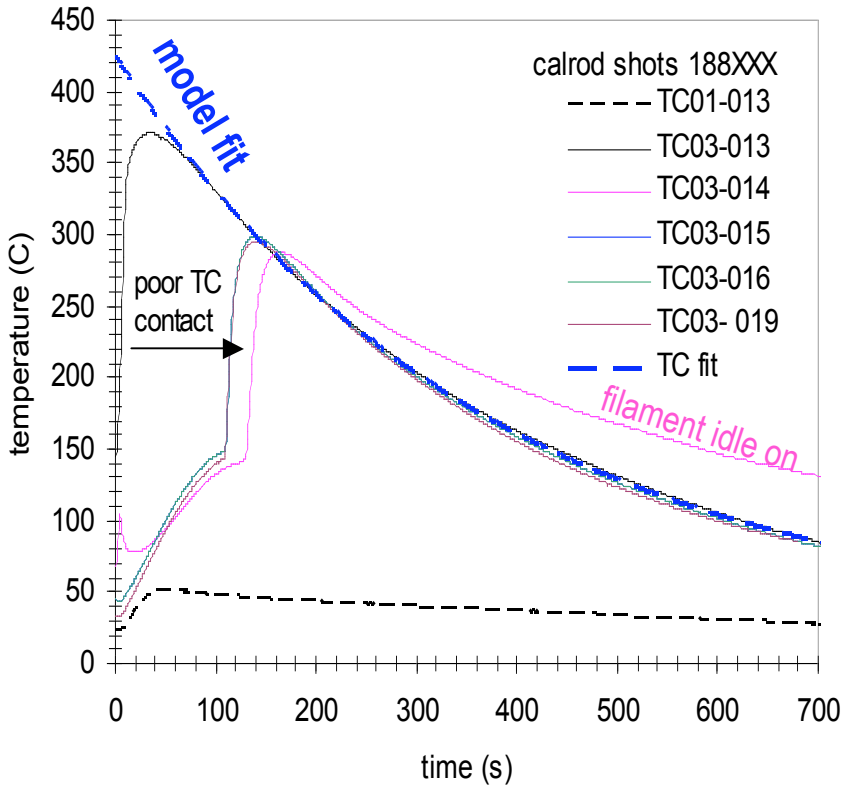
We did our calorimetry on an isolated W rod with a spring-loaded TC and a swaged ferrule.

The rod cooled by radiation. **Emissivity** and **q"** were varied in thermal model to obtain best fit to data.

$q''_{abs\text{-}model}/q''_{beam} = f_{abs}$





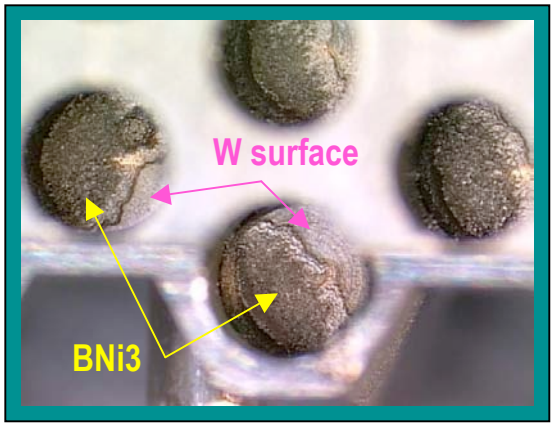
CalRod cooling curves

C-MOD tile – brazing

Carter Hodges & Chuck Walker – Sandia braze experts

Directive: Underfill the gap, restrict flow!

Amount of braze and time at temperature were minimized to reduce flow.



Braze and bottom of W rods in view down holes in Inconel base (final run, C-Mod tiles).

The flow and wetting characteristics of 3 Braze Filler Metals (BFMs) were tested using rod/base test clusters supplied by MIT.

		Solidus	Liquidous
Incusil® ABA:	**Ag-59.0, Cu-27.25, In-12.50, Ti-1.25**	**605°C**	**715°C**
Nioro®:	**Au-82.0, Ni-18.0**	**955°C**	**955°C**
Nicrobraz® 130*:	**B-3.1, Si-4.5, C-.06 max, Ni-Balance**	**980°C**	**1040°C**

***BNi3**

BFMs were applied in paste form to the bottom of the rods. The amount of paste was estimated during application by sight through a microscope.

S U C C E S S !